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SEASONAL VARIATIONS IN PHYTOPLANKTON AND ZOOPLANKTON POPULATION IN RELATION TO SOME ENVIRONMENTAL FACTORS AT THE TIDAL SANGU RIVER IN CHITTAGONG OF BANGLADESH

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Abstract

An experiment was carried out at two selected stations in the Sangu river estuary with the Bay of Bengal, Chittagong, Bangladesh to determine the abundance and monthly variations of phytoplankton and zooplankton communities as well as some physico-chemical parameters of water for a period of twelve months from August 2013 to July 2014. Water temperature, salinity and pH were recorded on the spot during each sampling. The NO_3-N and PO_4-P of the collected water samples were measured in the laboratory. The highest temperature (28.5^0 C at station I and 29^0 C at station II) was in September and the lowest (20^0 C at station I and 21.2^0 C at station II) in January. Salinity fluctuated from 13.0 to 32.0 ppt at station I in July and February, respectively and 15.0 to 33.0 ppt at station II in July and February, respectively. The highest pH (8.45) was recorded at station I in October. The highest NO_3-N (2.3 mg l^{-1} and 2.1 mg l^{-1} at station I and II, respectively) and PO_4-P (2.9 mg l^{-1} and 2.5 mg l^{-1} at station I and II, respectively) was recorded in August. In total 97 phytoplankton species were identified and 2 types could not be identified. Among the phytoplankton, 58 species belonged to Bacillariophyceae, 14 to Dinophyceae, 11 to Chlorophyceae, 6 to Cyanophyceae, 4 to Polycystinea and 4 to Polyhymenophorea. The highest phytoplankton production (117.3 × 10^3 cells l^{-1} at station I and 104.7×10^3 cells l^{-1} at station II) was found in August and the lowest (28.77 × 10^3 cells l^{-1} at station I and 29.6 × 10^3 cells l^{-1} at station II) in January. Phytoplankton bloom was observed in the study area in August. A total of 16 different zooplankton genera were recorded of which 12 belonging to Copepoda, 3 Rotifera and 1 Decapoda. Copepoda was the dominant group followed by Rotifera and Decapoda. The highest number of zooplankton (1,466 cells l^{-1} at station I and 1,198 cells l^{-1} at station II) was recorded in January and the lowest (280 cells l^{-1} at station I and 172 cells l^{-1} at station II) in August. The highest number of phytoplankton was appeared in August, which may be due to higher level of nutrients and water quality like temperature, salinity and pH were also within the favorable ranges. But zooplankton population was comparatively lower at that period owing to phytoplankton bloom. Therefore, the findings of this study would be helpful for the conservation of plankton community, biodiversity of the waters and congenial environment of the tidal waters.

Keywords: Seasonal variations, phytoplankton, zooplankton, nutrients, water quality parameters.

Introduction

Bangladesh is a land of rivers whose fresh water and salt water area occupies about 68,644.8 ha and 25,000 square miles, respectively (Raihana, 1984 and Zafar, 1986). Most of the people consume fish as main source of protein, although the supply of fish is not satisfactory. At present, fish consumption per capita per day is only 46.5 g whereas the actual requirement is about 49.3 g (BBS, 2008). Fish contribute around 4.37% to the GDP and 2.01% to national total foreign exchange earnings through export. Fish provide 60% of national animal protein consumption. Fisheries provide directly and indirectly livelihood to about 17.1 million people of the country (DoF, 2014).

The abundance and diversity of plankton affect the survival and growth rate of cultured fish in different ways. The role of plankton in fishery development is of great importance on their qualitative and quantitative distribution. The planktonic larvae of different species of aquatic organisms gradually transformed into post larval and juvenile stages in the estuaries and brackish water environment. Correct identification of post larval stages are also necessary for

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selective stocking in shrimp and fish culture system (Muthu, 1978). Therefore, intensive investigation on the qualitative and quantitative distribution of commercially important shrimp, fish and plankton in the coastal water of Bangladesh is essential.

Due to occupy the starting point of the food chain of the aquatic environment, phytoplankton have drawn the attention of many researchers. Both the qualitative and quantitative abundance of phytoplankton in a fish pond are of great importance in managing the successful aquaculture operations as they vary from location to location and depth to depth within the same location even within similar ecological conditions (Boyd, 1982; Hossain *et al*., 2007).

Zooplankton includes holoplanktonic organisms, whose complete life cycle lies within the plankton, and meroplanktonic organisms that spend part of their life cycle in the plankton before metamorphosis to either nekton or sessile and benthic existence. Zooplankton play an important role in aquatic food webs, both as a resource for consumers on higher trophic levels and as a conduit for packaging the organic material in the biological pump (Wikipedia, 2008).

Phytoplankton and zooplankton are distributed more or less throughout the world′s water bodies. So a thorough knowledge of abundance of phytoplankton and its quality has become a prerequisite for fish, shrimp and crab production. Existence of zooplankton production depends on the primary production. There is an interrelationship among phytoplankton, zooplankton and fish. Because of its great importance, attention should be given to the study of seasonal variations and abundance of zooplankton.

Many rivers including the Padma, the Meghna, the Jamuna, and the Brahmaputra receive fresh water run-off, which brings nutrients that enrich but in some cases eutrophic the estuarine and coastal waters. The nutrients receiving from freshwater run-off enhance phytoplankton growth. Growth of zooplankton and planktivorus fishes also depends on phytoplankton. So it is important to know the water quality status and plankton dynamics of coastal and estuarine waters of the Bay of Bengal. In most cases eutrophication triggers noxious toxic algal blooms and these are called harmful algal blooms (HABs). Harmful algal blooms due to nutrient enrichment in a different coastal water body of India have been reported (Santhanam *et al*., 1994).

The Sangu river meets with the Bay of Bengal and forming a typical estuarine system where many farms regularly discharge nutrients rich water and cause growth of plankton. So it is important to know the seasonal variation of plankton and water quality status of the Sangu river estuary and the effects of environmental factors on their occurrence, abundance and distribution for successful management and conservation of resourceful estuarine and coastal waters. Considering the above views, the present study was undertaken to determine the seasonal variations in species composition, occurrence and abundance of different species of plankton in relation to environmental factors at the Sangu river in Chittagong of Bangladesh.

Materials and Methods

***Study area*:** The Sangu river originates in the Alakan Hills of Myanmar and enters into Bangladesh near Remarki of Thanchi upazila of Bandarban district, and finally falls into the Bay of Bengal. The present study was carried out in the estuary of the Sangu river. Two spots /stations were selected in the Sangu river estuary at Chittagong for plankton sample. Samples were collected from the spots at day time. The experiment was carried out for a period of 12 months from August 2013 to July 2014. The necessary data were collected during the study period to fulfill the requirement of the research works.

Measurement of water quality parameters: Water quality parameters such as surface water temperature, salinity and pH were recorded respectively using a Celsius thermometer, portable refractometer and digital pH meter on the spot at monthly intervals. All the physical water quality parameters were determined in the field. Other water parameters were measured in the laboratory of Institute of Marine Sciences and Fisheries of Chittagong University. Water samples were collected on each sampling day. Plastic bottles were filled up with water from various spots. The bottles were than carried to the laboratory and 100 ml of water sample from each bottle was filtered through glass fiber filter paper (Whatman GF/C) for its analysis. Nitrate-nitrogen and phosphate-phosphorus (mg l^{-1}) were measured by an advanced Hach Kit (DR 4000, a direct reading spectrophotometer) using high range chemicals

(Nitraver 5 Nitrate Reagent Powder Pillows for 25ml sample for NO_3-N and Phosver 3 Phosphate Reagent Powder Pillows for 25ml sample for PO_4-P analysis).

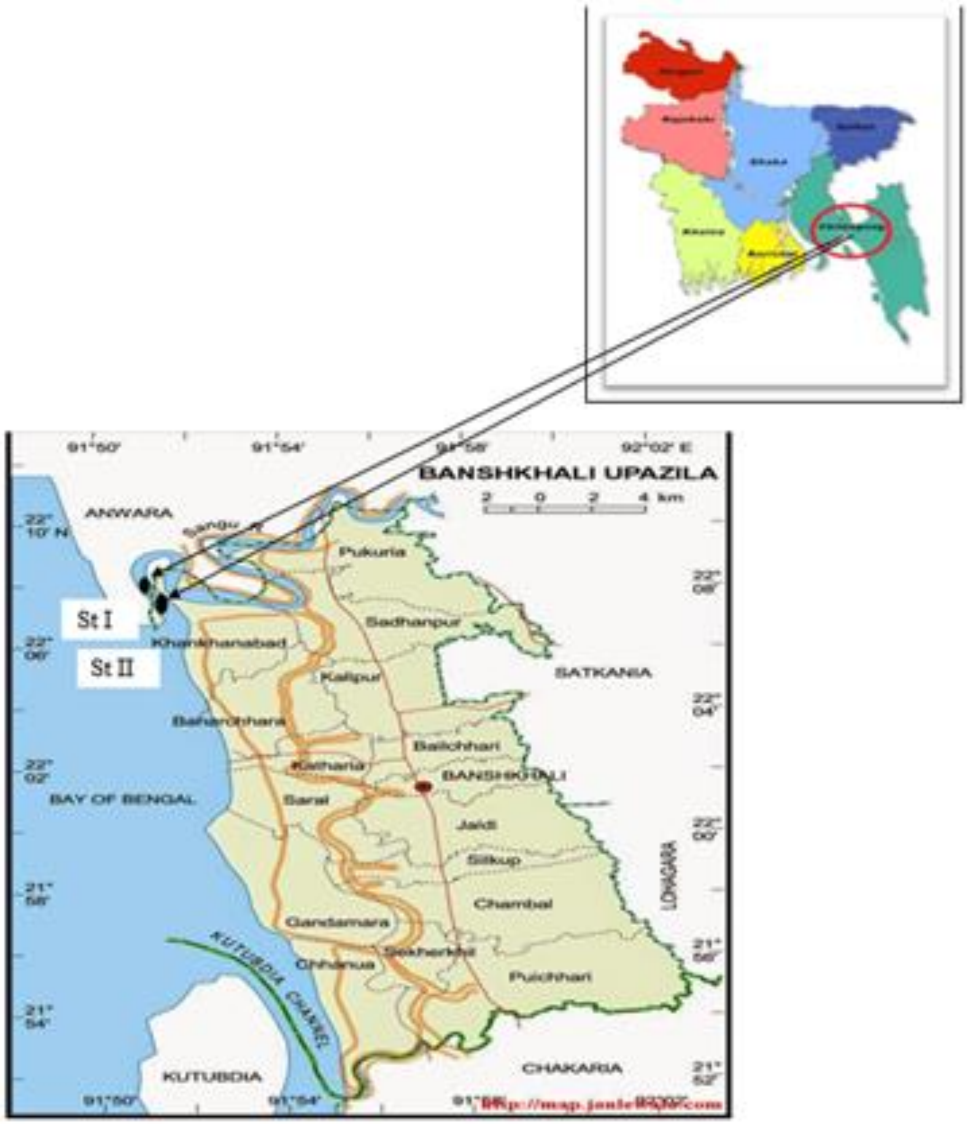

Fig. 1. Map of the Sangu river showing the study area.

Plankton estimation: Plankton samples were collected monthly from each of the study spots. Ten liter of water samples were collected from the spot and passed through fine meshed (25 µm) plankton net. Filtered samples were taken into a measuring cylinder and carefully measured. The volume of plankton samples were preserved in 10% buffered formalin in plastic bottles for subsequent analysis. From each of preserved samples, 1 ml sub-sample was examined for plankton estimation using Sedgewick-Rafter counting cell under a compound binocular microscope. The plankton liter^{-1} of original water was estimated applying the following formula (Rahman, 1992). Identification of plankton was done according to Prescott (1962), Bellinger (1992), Needham and Needham (1962) and Davis (1955).

$$N = \frac{A \times 1000 \times C}{V \times F \times L}$$

Here,

N=Number of plankton cells or units liter^{-1} of original water.

A=Total number of plankton counted.
C=Volume of final concentration of the sample in ml.
V=Volume of a field =1 cu mm.
F=Number of the field counted.
L= Volume of original water in litre.

Results and Discussion

Water quality parameters: During the study period, water temperature was obtained to vary from 20 - 28.5^{0}C and 21.2 - 29^0 C at station I and II, respectively and it showed clear seasonality. The highest temperature was found in September and the lowest in January. Barman (2013) found the lowest (25.0^{0}C) and the highest (31.0^{0}C) temperature in winter and monsoon, respectively at Karnafully river estuary, Bangladesh. Khan (2002) recorded the highest (32.5^{0}C) and the lowest (20.8^{0}C) temperature in August and December, respectively at the mouth of the Moheskhali channel, Bay of Bengal, Cox's Bazar. The present finding of water temperature was more or less similar with the findings of Barman (2013) and Khan (2002) and there is a positive relation with phytoplankton abundance (Fig. 2a). In the present study, salinity ranged from 13 - 32 ppt and 15 - 33 ppt at station I and station II, respectively. The highest salinity (33 ppt at station II) was found in January and the lowest (13 ppt at station I) in July (Fig. 2b). Salinity showed variations during the study period due to circulation in the Bay, rivers discharge, dilution and land run off due to rainfall. Khan (2002) reported the highest salinity (34 ppt) of water in April and the lowest (17.7 ppt) of the same in October at the Moheskhali channel of Bay of Bengal. Barman (2013) observed that the lowest (12 ppt) and the highest (21ppt) salinity in monsoon and pre-monsoon, respectively at Karnafuly river estuary, which was lower than the present findings. The level of pH ranged from 6.0 to 8.45 at station I and 7.0 to 8.40 at station II. At station I, the highest pH was in October (8.45) and at station II, it was in November (8.40) (Fig. 2c). Hossain (1999) recorded the highest pH value (9.45) in October and the lowest (7.1) in December at the Moheskhali channel, Bay of Bengal. Khan (2002) obtained the highest pH (8.6) in July and the lowest pH (6.8) in October at the Moheskhali channel of Bay of Bengal. Barman (2013) found the highest pH (6.5) in pre-monsoon and monsoon period and the lowest pH (4.5) in post monsoon at the Karnafully river estuary.

Nutrients levels revealed similar seasonal cycles in the study sites. Nitrate nitrogen concentration varied from 0.9 mg l^{-1} to 2.2 mg l^{-1}. The lowest (0.9 mg l^{-1}) and highest (2.2 mg l^{-1}) nitrate concentrations were recorded in July and August, respectively (Fig. 2d). The results of the present study was similar to the findings of Jewel *et al*. (2002), who reported 0.8 to 3.0 mg l^{-1} nitrate-nitrogen at the mouth of the Moheshkhali channel of the Bay of Bengal. Khan (2002) observed the highest (1.7 mg l^{-1}) and the lowest (0.2 mg l^{-1}) nitrate nitrogen concentration in August and June, respectively in the Moheskhali channel, Bay of Bengal. Shah *et al.* (2008) recorded the highest nitrate concentration (1.9 mg l^{-1}) in May and the lowest (0.7 mg l^{-1}) in September in the Shibsa river of the southwest coast of Bangladesh which was more or less coincided with present findings. Fluctuation of PO_4-P concentration ranged from 1.5 to 2.9 mg l^{-1} with maxima and minima recorded in August and December, respectively (Fig. 2e). Jewel *et al*. (2002) reported the highest phosphate phosphorous concentration (3.2 mg l^{-1}) in November and the lowest (0.06 mg l^{-1}) of the same in May at the Moheskhali channel. Khan (2002) found the highest (1.1 mg l^{-1}) and the lowest (0.1 mg l^{-1}) phosphate-phosphorous in November and June, respectively at Moheskhali channel. Hossain (1999) recorded the highest (4.9 mg l^{-1}) and the lowest (1.9 mg l^{-1}) phosphate phosphorous concentrations in August and December, respectively at Moheskhali channel. The values of the present findings were within the ranges of above mentioned researcher's findings.

Phytoplankton density: The species of phytoplankton recorded during the present study are shown in Table 1. Of different phytoplankton species recorded, 58 belonged to Bacillariophyceae, 14 to Diniphyceae, 11 to Cholorophyceae, 6 to Cyanophyceae, 4 to Polycestinea and 4 to Polyhymenophora. Phytoplankton occurrence and distribution did not follow any uniform pattern. Dinophyceae was the dominant group in August and September but it found round the study period. Except in August and September, Bacillariophyceae was the most dominant group of phytoplankton throughout the study period. Chlorophyceae found round the year with fewer abundance (Fig. 3a and 3b). Islam and Aziz (1975, 1980) described 31 genera of Bacillariophyceae, 4 genera of Dinophyceae and 2 genera of Cyanophyceae from the inshore waters of the Bay of Bengal near Moheshkali and Sonadia islands. In different seasons from the offshore waters of the Bay of Bengal 10 genera of Chlorophyceae, 21 genera of Bacillariophyceae, 3 genera of Dinophyceae and 5 genera of Cyanophyceae were recorded (Mahmood *et al*., 2006).

Table 1. List of phytoplankton species recorded in the study area during the study period of August 2013-July 2014.

Bacillariaophyceae	
Chaetoceros affinis	*Gyrosigma* spp.
C. atlanticus	*Tephanopysis palmeriana*
C. didymus	*Thalassiosira* sp.
C. distans	*Asteromphalus flabellatus*
C. diversus	*A. hookerii*
C. indicus	*Coscinodiscus extravagans*
C. paradoxus	*C. lineatus*
Stictodiscus gravei	*C. radiates*
Stictocyclus varicus	*Nitzschia acicularis*
Rhizosolenia alata	*N. sigmoidea*
R. bergonii	*N. lungarica*
R. indica	*N. palea*
Bacteriastrum elongatum	*Surirella biserita*
Biddulphia azorica	*Cyclotella operculata*
B. mobiliensis	*C. glomerata*
B. sinensis	*C. compta*
Ditylum brightwellii	*Triceratium albifrons*
Hemiaulus indicus	*T. formosum*
H. membranaceus	*T. impressum*
Thalassiothrix frauenfeldii	*T. radians*
Thalassionema nitzschiodes	*T.* spp.
Cocconeis scutellum	*Diploneis splendica*
Amphiprora alata	*Pleurosigma normanii*
Amphora laevis	*Nitzschia seriata*
Campylodiscus grauffei	*Synedra ulna*
Asterionella glacialis	*S. pelagic*
Surirella gemma	*Navicula distans*
Bacillaria paxillifer	*N. robortsiana*
Grammatophora marina	*Grammatophera marina*
Dinophyceae	
Dinophysis caudata	*Protogonyaulax catenella*
D. mitra	*Triposolenia bicornis*
D. homunculus	*Ceratium belone*
Prorocentum micans	*C. furca*
Balechina coerulea	*C. lunula*
Gymnodinum coeruleum	*Ceratocorys* sp.
Gonyaulax polyedra	*Noctiluca scintillans*
Chlorophyceae	
Coleochaete sp.	*Ulothrix aequalies*
Melosira varians	*Tetraspora Geletinosa*
Aulacoseira granulate	*Scenedesmus Acutus*
Spirogyra sp.	*S. quadricau*
Microspora floccose	*Golenkinia radiate*
Cosmarium bioculatum	
Cyanophyceae	
Oscillatoria sp.	*Nostoc pruniforme*
Aphanizomenon flos-aquae	*Microcystis flos-aquae*
Anabaeca flos-aquae	*Trichodesmium erythaeum*

Polycystinea

Centracontarum hexacontarium
Cromyodrymes abietinues
Euchitonia sp.
Heliodiscus asteriscus

Polyhymenophorea

Codonaria australis
Codonella sp.
Favella ehrenbergii
Rhabdonella poculum

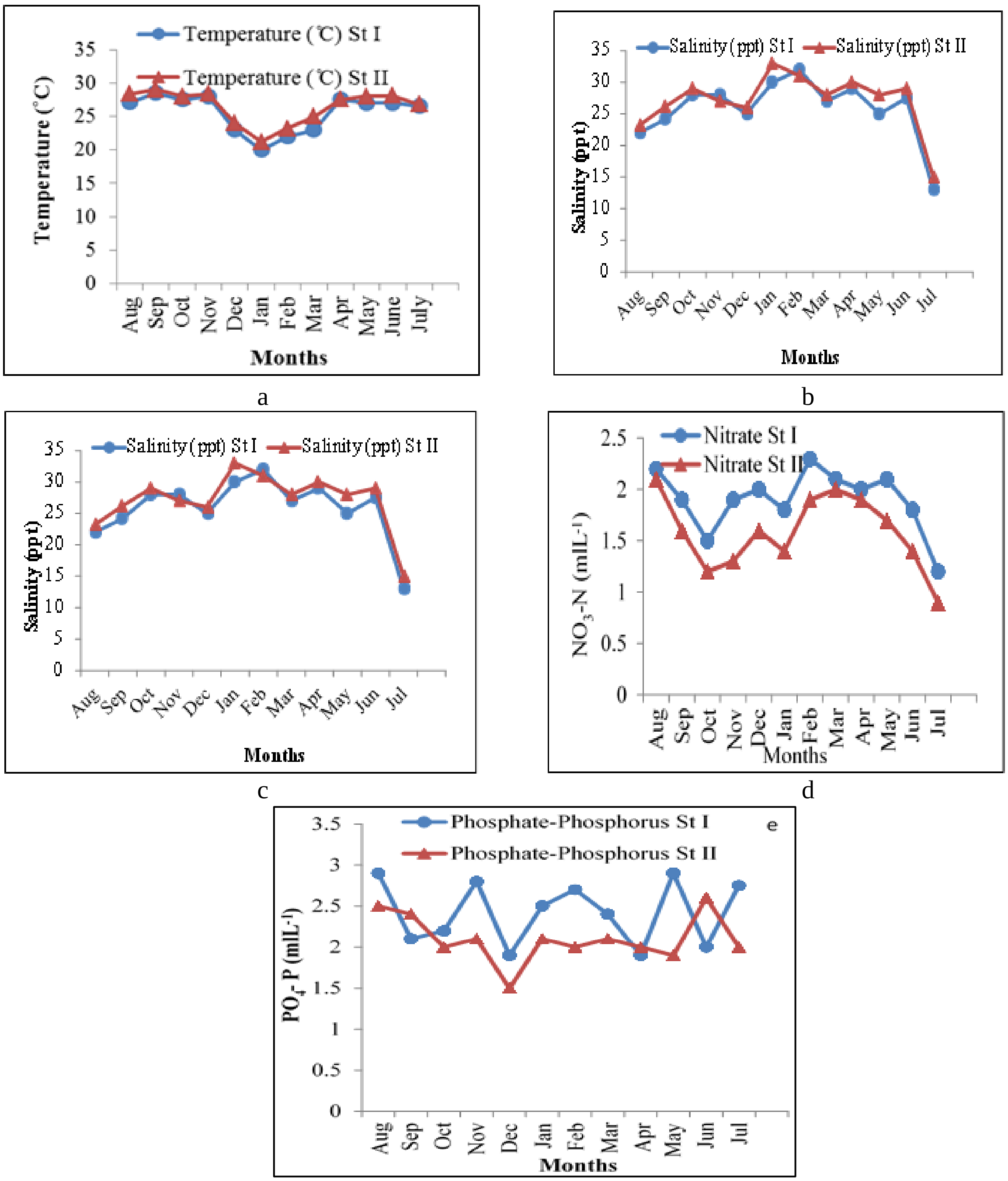

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Fig. 2 (a-e). Monthly variations of some water quality parameters at station I and II during study the period.

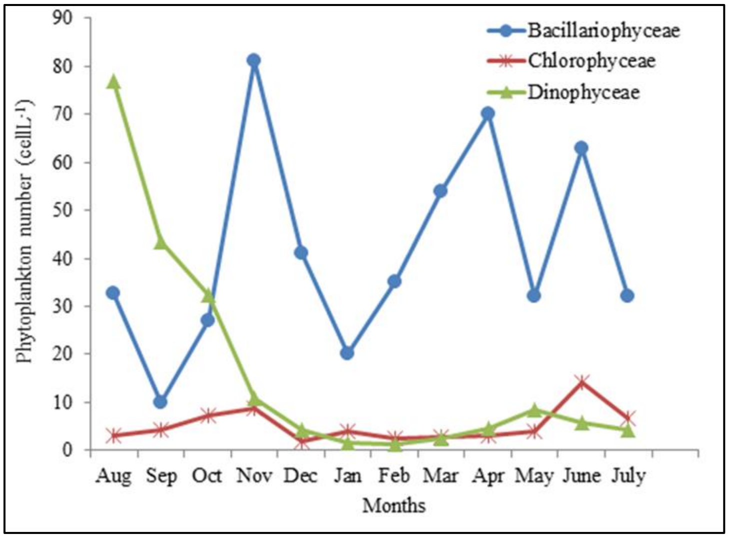

Fig. 3a. Seasonal fluctuations of dominant phytoplankton groups (Bacillariophyceae, Chlorophyceae and Dinophyceae) at station I during the study period.

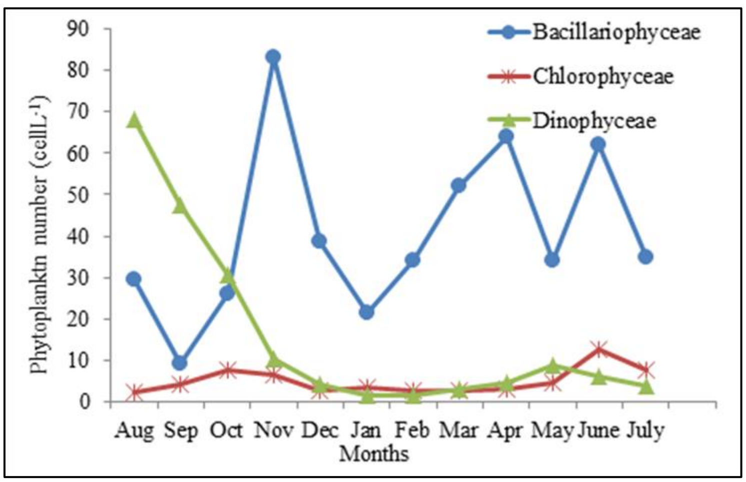

Fig. 3b. Monthly fluctuation of dominant phytoplankton groups (Bacillariophyceae, Chlorophyceae and Dinophyceae) at station II during the study period.

The highest cell of phytoplankton were 117.3×10^3 cells l^{-1} at station I and 104.7×10^3 cells l^{-1} at station II during the rainy season (Fig. 4). Mahmood *et al*. (2006) recorded the highest phytoplankton count during monsoon due to higher level of nutrients in the southeast coast of Bangladesh from St. Martin's Island to the Karnafully river estuary. Maximum phytoplankton cell in the coastal water of the Sangu river were (117.3×10^3 cells l^{-1} at station I and 104.7 x 10^3 cells l^{-1} at station II) in August and minimum phytoplankton densities in the study sites were (28.77×10^3 cells l^{-1} at station I and 29.6×10^3 cells l^{-1} at station II) in January. The present findings were comparable to those observed by Mahmood *et al*. (2006) who obtained $33.42\text{-}222.69 \times 10^2$ cells l^{-1} in monsoon period in the southeast coast of Bangladesh from St. Martin's Island to karnafully river estuary and Fernandez *et al.* (1993) who encountered 4000 cells l^{-1} in monsoon in the southern Bay of Biscay. Rahaman *et al.* (2013) enumerated 1.015×10^5 cells l^{-1} in summer in Rupsha-Pashur, 4.197×10^5 cells l^{-1} in winter in Khalpatua-Arpangachia and 5.03×10^5 cells l^{-1} in summer in Bhola-Baleswar river system of the coastal waters of Bangladesh.

Higher similar phytoplankton growth due to nutrient accumulation during rainy season from September to November in Maputo Bay was observed by Paula *et al.* (1998). It was reported elsewhere that the availability of nutrients in the coastal waters was related to rainfall and connected river discharge (Kitheka *et al.*, 1995). Khan (2002) obtained the highest phytoplankton cells (27.17 x 10^5 cells l^{-1}) during the late rainy season. Jewel (2001) recorded the highest (57.8 × 10^6 cells l^{-1}) phytoplankton production during the late rainy season. Hossain (1999) reported the highest (11.85 × 10^6 cells l^{-1}) number of phytoplankton in rainy season (August) in the Moheskhali channel, Bay of Bengal. It was reported that higher primary productivity in different estuarine and coastal was observed during rainy season (Bryceson, 1977; Lugomela, 1995; Kitheka *et al.*, 1995). The rain cycle seems to be the main factor controlling the seasonality of plankton assemblages in the observed estuarine waters.

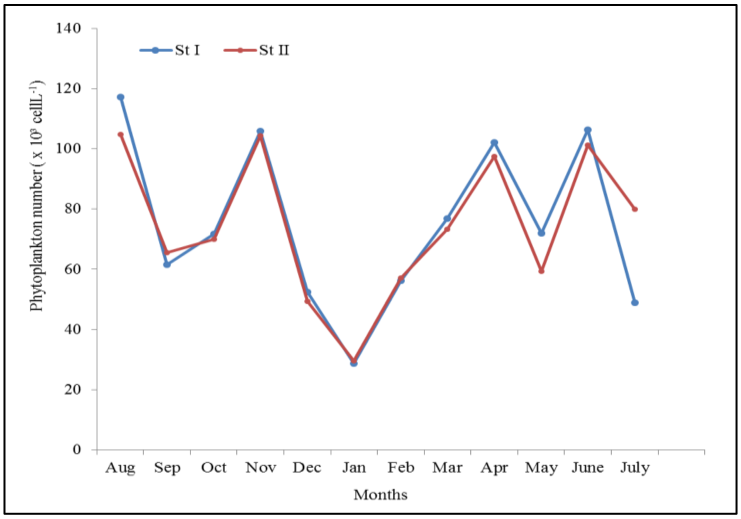

Fig. 4. Seasonal fluctuations of total phytoplankton at station I and II during the study period.

Bloom of toxic dinoflagellate, *Dinophysis caudata* was observed in the Bay of Bengal, which might be due to flood waters carrying nutrients of agricultural, industrial and sewage origin as well as discharged as runoff through many rivers to the Sangu river, Bangladesh and that was supposed to trigger the toxic algal bloom. High concentrations (2.9 mg l^{-1}) of phosphate phosphorus were recorded during the bloom months (August-September 2014) that might have a relationship with the bloom. Mahmood *et al.* (2006) reported highest phytoplankton count during monsoon season can be explained by the higher level of nutrients, particularly phosphate and nitrate during this period in the southeast coast of Bangladesh. Santhanam and Srinivasan (1996) reported phosphate-phosphorus accumulation through runoff waters in the coastal water of the Tuticorin Bay of India that Triggered *D. caudata* bloom. Santhanam and Srinivasan (1996) recorded the highest phytoplankton cell number (1.1 × 10^6 cells l^{-1}) during monsoon months in the Tuticorin Bay of India, which was supposed to be caused by continuous discharge of sewage water during the rainy periods. They also observed considerable variations in species composition during the study period and found diatom as a dominant group round the year except in August and September when dinoflagellates formed blooms. Mahmood *et al.* (2006) also reported centric diatoms were higher than that of pinnate during the three seasons (premonsoon, monsoon and postmonsoon) in the southeast coast of Bangladesh from St. Martin's Island to the Karnafully estuary.

The phytoplankton community at the two sampling stations differed slightly from one to other. Indeed, phytoplankton species distribution was related to several factors like as salinity, temperature, pH, nitrate nitrogen and phosphate phosphorus. These differences in environmental condition can be explained by the position of the stations. Station I, positioned about 1.5 km upstream from the mouth of the Sangu in the Bay of Bengal is obviously more influenced by the discharge of the river waters, which explains the lower salinity. The rain cycle thus seem to be the main factor controlling the seasonally of plankton assemblages in the observed estuarine waters. There was no significant difference in phytoplankton species composition and abundance between the two stations. These could be due to the above mentioned almost similar environmental conditions.

Zooplankton density: The identified species of zooplankton are furnished in Table 2. Among 16 identified taxa 12 belonged to Copepoda, 3 to Rotifera and 1 to Decapoda. Some of them occurred during each sampling month and some did not found in every month (Table 2). Al Masum (2005) found 16 groups of zooplankton from three different stations of Karnafully river estuary in post monsoon (04 December to 05 February), premonsoon (05 March to 05 May) and monsoon (05 June to 05 August). He reported maximum densities of zooplankton during post monsoon period (263.6185% ind/m^3) and minimum density in monsoon (69.132 ind/m^3). Copepods were the dominant taxa in the zooplankton.

The zooplankton were most abundant (1,466 ogranisms l^{-1} at station I and 1,198 ogranisms l^{-1} at station II) in January and least abundant (280 ogranisms l^{-1} at station I and 172 ogranisms l^{-1} at station II) in August (Fig. 4). The finding of present investigation was strongly agreed with the findings of Al Masum (2005).

Copepods were found to be the most dominant group in the zooplankton, 71 - 88% at station I and 74 - 85% at station II of the total population. Each species of Copepoda showed remarkable fluctuation during the period of study. It contained 12 genera. These were *Calanus helgolandicus*, *Microcalanus pusillus*, *Paracalanus parvus*, *Temora longicornis*, *Acartia clause*, *Centropages typicus*, *Candacia armata*, *Cyclops*, *Diaptomus* sp., *Oithona helgolandica*, *Tigriopus* sp. and *Nauplius*. Of these, *Cyclops*, *Diaptomus* and *Nauplius* were the most dominant genera. *Nauplius* occurred throughout the study period but was abundant in January. Khan (1995) reported two peaks of zooplankton during post monsoon and pre monsoon in the Hugli-Malta estuarine system. According to Islam and Hossain (1982) Copepods comprised the bulk of total zooplankton fauna in all three seasons in the entire estuarine system. The contribution was higher during the post monsoon when high salinity prevailed in the entire estuary. The present investigation was strongly supported by the finding of those authors.

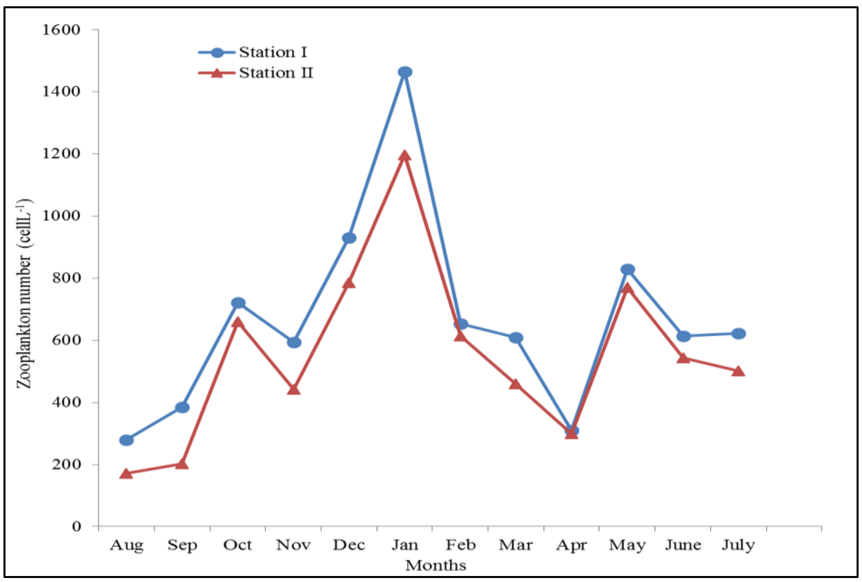

Fig. 5. Seasonal variations of total zooplankton at station I and station II during the study period.

Rotifera were the next dominant group and showed noticeable fluctuation in their abundance during the investigation period. Rotifers showed the maximum abundance (195 ogranisms l^{-1} at station I and 236 ogranisms l^{-1} at station II) in January and minimum (25 ogranisms l^{-1} at station I and 21 ogranisms l^{-1} at station II) in August. Rotifers contained 3 genera like as *Trichocerca* sp., *Keratella* sp. and *Brachionus* sp. In some samples one or more were not represented. Among the three genera, *Trichocerca* was most dominant (75 ogranisms l^{-1} at station I and 76 ogranisms l^{-1} at station II) in January. Decapoda was found to be the least available group in the zooplankton population. It contained only one genera *viz*., *Processa*. Decapods were abundant (84 ogranisms l^{-1} at station I and 76 ogranisms l^{-1} at station II) in October (Fig. 5). Goswami and Devassy (1991) reported that Cladocerans and Decapoda were absent in the premonsoon due to lack of favorable condition associated with low nutrient levels and phytoplankton abundance. Islam and Hossain (1982) also found that Cladocera and Decapoda were few during the post-monsoon. Al Masum (2005) obtained that Cladocerans and Decapoda were absent at post-monsoon and very few were present at the others. The present finding was agreed with the findings of above researchers.

The results of the present study on phytoplankton and zooplankton in the Sangu river estuary are very much important for the coastal waters. Efforts were made to retrieve data on the records of phytoplankton abundance, primary productivity and water quality parameters like water temperature, pH, salinity, nitrate nitrogen (NO_3-N) and phosphate phosphorus (PO_4-P) from the study area. The abundance of plankton was varied from one place to another. The abundance of plankton was also varied according to the water temperature, pH and other water quality parameters. These findings will be helpful for the conservation of plankton community, biodiversity of the waters and congenial environment of the Sangu river ecosystem and other tidal waters.

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